

Efficacy of electrical stimulation in preventing or reducing subluxation of the shoulder after stroke: A meta-analysis

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After stroke, up to 81% of individuals develop shoulder subluxation, a condition frequently associated with poor upper limb function. Recently, electrical stimulation has been applied to shoulder muscles to treat shoulder subluxation. The purpose of this meta-analysis was to examine the efficacy of surface electrical stimulation for the prevention or reduction of shoulder subluxation after stroke. A meta-analysis of all eligible randomised or quasi-randomised trials of electrical stimulation for the treatment of shoulder subluxation identified by computerised and hand searches of the literature was carried out. The primary outcome measure of interest was subluxation. Seven (four early and three late) trials met the inclusion criteria. The mean PEDro score out of 10 for quality of the methods was 5.8 for the four early trials and 4.3 for the three late trials. Data were pooled when subluxation was measured in millimetres. Analysis found that, when added to conventional therapy, electrical stimulation prevented on average 6.5mm of shoulder subluxation (weighted mean difference, 95% CI 4.4 to 8.6) but only reduced it by 1.9mm (weighted mean difference, 95% CI -2.3 to 6.1) compared with conventional therapy alone. Therefore, evidence supports the use of electrical stimulation early after stroke for the prevention of, but not late after stroke for the reduction of, shoulder subluxation. [Ada L and Foongchomcheay A (2002): Efficacy of electrical stimulation in preventing or reducing subluxation of the shoulder after stroke: A meta-analysis. *Australian Journal of Physiotherapy* 48: 257-267]

Key words: Cerebrovascular Disorders; Electrical Stimulation Therapy; Meta-Analysis; Shoulder Dislocation

Introduction

Inferior glenohumeral joint displacement, generally referred to as shoulder subluxation, is one of the most common secondary musculoskeletal impairments in the upper limb after stroke. The incidence in the period soon after stroke ranges from 7% to 81% and this variation appears to be related to the degree of paralysis of the muscles in the upper limb. For example, Najenson et al (1971) reported an 81% incidence, Smith et al (1982) reported a 60% incidence and Miglietta et al (1959) reported a 56% incidence in stroke patients who had no active motion at the shoulder. The incidence was lower (40%) in stroke patients who had some activity in their upper arm (Linn et al 1999). Similarly, Chaco and Wolf (1971) and Hurd et al (1974) reported only a 15% and 7% incidence respectively, in stroke patients who had activity of the upper limb muscles within one month.

Shoulder subluxation is considered to be a problem because it causes shoulder pain and hinders the recovery of upper limb function. It has been suggested that subluxation causes shoulder pain by overstretching the soft tissues (such as the capsule, ligaments and muscles) surrounding the shoulder (eg Cailliet 1980, Chino 1981, Shai et al 1984). However, most studies report no significant correlation between subluxation and pain (Bohannon and Andrews 1990, van Langenberghe and Hogan 1988, Zorowitz et al 1996). It is now thought that subluxation is

only one of several factors that can cause shoulder pain after stroke. On the other hand, there is evidence to suggest that shoulder subluxation is associated with poor upper limb function (Hanger et al 2000) and reflex sympathetic dystrophy (Dursun et al 2000). Therefore, its prevention should be an important part of upper limb rehabilitation.

After stroke, as a result of paralysis, the gravitational pull on the humerus causes stretching of the capsule of the shoulder joint, resulting in inferior subluxation. Electromyographic studies show that the supraspinatus muscle and to a lesser extent the posterior deltoid muscle are key components in counteracting this downward pull (Basmajian and Bazant 1959, Chaco and Wolf 1971). Recently, electrical stimulation has been applied to these muscles (Baker and Parker 1986, Chae et al 2001, Chantraine et al 1999, Faghri et al 1994, Kobayashi et al 1999, Linn et al 1999, Mackenzie-Knapp 1999, Wang et al 2000, Yu et al 2001) in an effort to treat shoulder subluxation. There have been some narrative reviews of the efficacy of electrical stimulation in individuals after stroke (Binder-Macleod and Lee 1997, Chae and Yu 2000, Kimberley and Carey 2002, Morley et al 2002) and one systematic review investigating the effect of surface electrical stimulation on pain (Price and Pandyan 2001a and 2001b). The systematic review by Price and Pandyan investigated subluxation as a secondary outcome measure, and a motor response from the electrical stimulation was therefore not part of inclusion criteria. If the aim is to prevent subluxation, it is important that the electrical

Table 1. Identified trials.

Study	Inclusion criteria						Comments	Decision
	RCT/ Quasi RCT	Stroke only	Age > 50 years	Surface ES	Motor response to ES	Outcome of interest		
Baker and Parker 1986	✓	✓	✓	✓	✓	✓		I
Chae et al 2001	X	✓	✓	X	✓	✓	1 case	E
Chantraine et al 1999	✓	X	✓	✓	✓	✓		E
Faghri et al 1994	✓	✓	✓	✓	✓	✓		I
Kobayashi et al 1999	✓	✓	✓	✓	✓	✓		I
Leandri et al 1990	✓	✓	✓	✓	X	✓		E
Linn et al 1999	✓	✓	✓	✓	✓	✓		I
Mackenzie-Knapp 1999	X	✓	X	✓	✓	✓	1 case	E
Sonde et al 1998	✓	✓	✓	✓	X	✓		E
Wang et al 2000	✓	✓	✓	✓	✓	✓		I
Wang et al 2002	✓	✓	✓	✓	✓	✓		I
Yu et al 2001	✓	✓	✓	X	✓	✓		E

✓ = meets inclusion criteria, X = does not meet inclusion criteria. RCT, randomised controlled trial. ES, electrical stimulation. I, inclusion. E, exclusion.

stimulation produces a motor response in the supraspinatus and the posterior deltoid muscles, since these muscles have been shown to be important in maintaining normal glenohumeral alignment (Basmajian and Bazant 1959, Chaco and Wolf 1971).

Therefore, we conducted a meta-analysis with the primary purpose of examining the efficacy of surface electrical stimulation which produced a motor response in the supraspinatus and/or posterior deltoid muscles in (i) preventing and (ii) reducing subluxation of the shoulder. The secondary purpose was to examine the efficacy of surface electrical stimulation in (i) improving function of the shoulder early after stroke and (ii) late after stroke. The tertiary purpose was to examine the efficacy of surface electrical stimulation in (i) preventing and (ii) reducing pain in the shoulder.

Methods

Identification and inclusion of trials Computerised bibliographic databases: MEDLINE (1966-2002), CINAHL (1982-2002), AMED (1985-2002), EMBASE (1974-2002) and the Cochrane Controlled Trials Register (Cochrane Library Issue 2, 2002) were searched from the first available year up until July 2002. Searches were performed using key words (MeSH) related to stroke, electrical stimulation and shoulder disorders, without language restrictions. Relevant studies were identified from titles and abstracts (where available) by one reviewer and full paper copies were obtained. Additional studies were identified from reference lists of the relevant trials and by hand searching of relevant conference proceedings.

To determine whether a trial should be included, two reviewers independently used predetermined criteria. These criteria were that: the trial was randomised or quasi-randomised; participants had a clinical diagnosis of stroke (with or without a CT scan); the average age of participants was more than 50 years; intervention was surface electrical stimulation; the stimulation frequency used was greater than 30 Hz, or it was otherwise reported that a motor response was obtained; and subluxation or pain or function was measured as an outcome. There was no exclusion on the basis of previous stroke but studies that included participants with other neurological conditions were omitted. Studies in which electrical stimulation was only one part of a multiple intervention were also excluded. Blinding of the assessor was recorded but was not a criteria for inclusion.

To be included, both reviewers had to agree that the trials met these criteria. Disagreements about the inclusion of trials were resolved by discussion. Included trials were then categorised as either (i) early electrical stimulation or (ii) late electrical stimulation. Trials that included participants with a stroke less than two months before being admitted into the study were categorised as early electrical stimulation and trials that included participants who had had a stroke more than two months before being admitted into the study were categorised as late electrical stimulation.

Similarity of inclusion criteria, sample characteristics, intervention, outcome measures between trials Two reviewers independently extracted details such as inclusion criteria, sample characteristics, intervention and outcome measures. Similarity of these aspects between the included trials was examined by two reviewers.

Table 2. Characteristics of included trials.

Study	Baker	Faghri	Kobayashi-D, Kobayashi-S	Linn	Wang-E, Wang-L
Quality (PEDro score)	4/10	5/10*	4/10	9/10*	5/10
Design	Parallel group design Randomised Concealment: unknown Exp: Conventional hemi-sling, wheelchair arm support + electrical stimulation C: Conventional hemi-sling, wheelchair arm support	Parallel group design Randomised Concealed Exp: Conventional therapy + electrical stimulation C: Conventional therapy	Parallel group design Quasi-randomised Concealment: unknown Exp: Neuro-muscular facilitation, joint mobilisation, stretching + electrical stimulation C: Neuro-muscular facilitation, joint mobilisation, stretching	Parallel group design Randomised Concealed Exp: Conventional PT and OT + electrical stimulation C: Conventional PT and OT	Parallel group design Randomised Concealment: unknown Exp: Conventional therapy + electrical stimulation C: Conventional therapy
Inclusion criteria	Subluxation	Shoulder muscle paralysis	Subluxation	Manual muscle test for upper limb ≤ 2 , reasonable communication ability	Subluxation
Sample characteristics	Average age: Exp/C = 56/55 yr Average time after stroke: Exp/C = 49/46 days N = 63, M/F = 31/32, R/L = 29/34	Average age: Exp/C = 65/69 yr Average time after stroke: Exp/C = 16/17 days N = 26, M/F = 15/11, R/L = 9/17	Average age: Exp/C (Kobayashi-D) = 69/53 yr (Kobayashi-S) = 59/53 yr Average time after stroke: Exp/C (Kobayashi-D) = 95/190, (Kobayashi-S) = 60/190 days N = 22, M/F = 20/2, R/L = 12/10	Average age: Exp/C = 71/73 yr Average time after stroke: Exp/C = 2/2 days N = 40, M/F = 18/22, R/L = 9/31	Average age: Exp/C (Wang-E) = 56/56 yr (Wang-L) = 58/58 yr Average time after stroke: Exp/C (Wang-E) = 16/15, (Wang-L) = 427/434 days N = 32, M/F = 16/16, R/L = 15/17 Note: 2 sub groups; early and late electrical stimulation
Application of electrical stimulation	Treatment time: increased from 0.5-7 hr/session, 1-3 session/d, 5 d/wk, 6 wk Electrical stimulation: 12-25 Hz (tetanised muscle contraction), electrodes placed on supraspinatus and deltoid muscles	Treatment time: increased from 1.5-6 hr/session, 1 session/d, 7 d/wk, 6 wk Electrical stimulation: 35 Hz, electrodes placed on supraspinatus and deltoid muscles	Treatment time: 15 min/session, 2 session/d, 5 d/wk, 6 wk Electrical stimulation: 20 Hz (strong contraction, sufficient to reduce subluxation which was confirmed by x-ray) Note: 2 treatment groups; deltoid and supraspinatus	Treatment time: increased from 0.5-1 hr/session, 4 session/d, 7 d/wk, 4 wk Electrical stimulation: 30 Hz, electrodes placed on supraspinous fossa and posterior aspect of upper arm	Treatment time: increased from 0.5-6 hr/session, 3-1 session/d, 5 d/wk, 6 wk Electrical stimulation: 10-24 Hz (tetanised muscle contraction), electrodes placed on supraspinatus and posterior deltoid

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Study	Baker	Faghri	Kobayashi-D, Kobayashi-S	Linn	Wang-E, Wang-L
Outcome measures	Subluxation: in mm (compared both sides), method: unknown	Subluxation: in mm (compared both sides), vertical distance from most inferior and lateral point on acromial surface of the acromioclavicular joint to the central point of the humeral head	Subluxation: in mm (compared both sides), vertical distance from inferior border of glenoid fossa to inferior line through anatomical neck of humeral head	Subluxation: grading 0-4 and in mm (only affected side), vertical distance from mid-point of glenoid fossa to the most superior aspect of head of humerus Note: smaller number=larger subluxation	Subluxation: in mm (only affected side), vertical distance from inferior border of acromion to superior aspect of humeral head
	Pain: subjective self report, request for analgesic drug	Pain: pain-free range of passive external rotation of the shoulder (compared both sides)	Pain: VAS (15 cm scale) on active shoulder abduction	Pain: pain-free range of passive external rotation of shoulder of the affected side, and grading verbal scale from none (0) to severe (4)	Pain: pain-free range of active external rotation of shoulder of the affected side
	Arm function: nil	Arm function: Bobath assessment chart, EMG of posterior deltoid	Arm function: max isometric abduction contraction	Arm function: MAS (upper arm part)	Arm function: Fugl-Meyer
	Time of measurement: before, after 6 wk of treatment, 3 month F/U	Time of measurement: before, after 6 wk of treatment, 6 wk F/U	Time of measurement: before, after 6wk of treatment, No F/U	Time of measurement: before, after 4 wk of treatment, 8 wk F/U	Time of measurement: before, after each 6 wk phase, 6 wk F/U
	Assessor: one of two was blinded	Assessor: blinded	Assessor: blinding uncertain	Assessor: blinded	Assessor: blinded

Exp = experimental group, C = control group, PT = physiotherapy, OT = occupational therapy, mm = millimetres, N = number of subjects, M = male, F = female, R = right side hemiplegia, L = left side hemiplegia, F/U = follow up. VAS, visual analogue scale. MAS, motor assessment scale.

*These scores are higher than those recorded on PEDro because additional information was obtained from the authors.

Quality of trials One reviewer assessed the methodological quality of included trials using the PEDro scale (Moseley et al 2002), which is based on the Delphi List (Verhagen 1998) and available at the Centre for Evidence-Based Physiotherapy website (<http://ptwww.cchs.usyd.edu.au/pedro/scaleitems>). The scale assesses: specification of eligibility criteria; random allocation to groups; concealed allocation; groups similar at baseline; blinding of subjects, therapists and assessors; outcome measurements obtained from more than 85% of subjects; statistical comparisons between groups; and reporting of point measures and measures of variability.

Analysis of data Number of participants, means and standard deviations of outcome measures were extracted. Where data were not available in the published studies, details were requested from the first-named or corresponding author. Where raw data were available, means and SDs of change scores were calculated. Otherwise, means and standard deviations of post-intervention data were used. If standard deviations were not available, they were calculated from the standard errors. Where standard errors could only be determined from published graphs, the average value from three estimators was used.

Trials using similar methods of measurement for the primary outcome of subluxation or the secondary outcome of function or the tertiary outcome of pain at similar times post-intervention were considered for pooling. Then the data were entered into the Cochrane Collaboration's Review Manager software program (RevMan 4.1) and pooling was carried out. Where the same methods of measurement were used, the effect sizes were reported as weighted mean differences and 95% CI, and a fixed effects model was used. Where different methods of measurement were used, the effect size was reported as standardised mean differences and 95% CI, and a random effects model was used. A test of heterogeneity of the data was performed and if significant ($p < 0.1$ using the Q statistic) the source of heterogeneity was investigated by doing a sensitivity analysis.

Results

Identification and selection of trials Sixty-seven references were retrieved from the search strategy. Eighteen relevant studies were identified; however, six of these 18 studies were reviews rather than experiments. Therefore, 12 studies were assessed for inclusion (Table 1). Studies were excluded because: they were not randomised or quasi-randomised trials (Chae et al 2001, Mackenzie-Knapp 1999); they included participants suffering from both brain injury and stroke and separate data for stroke participants could not be obtained (Chantraine et al 1999); they included very young stroke subjects (Mackenzie-Knapp 1999); they used implanted electrodes (Chae et al 2001, Yu et al 2001); or they used non-motor parameters of electrical stimulation (Leandri et al 1990, Sonde et al 1998). Six studies met the inclusion criteria according to both reviewers. Two of these six (Wang et al 2000, Wang et al 2002) are reports of different outcome measures from the same intervention on the same subjects and were therefore considered as one study. However, they reported two categories of participants according to time after stroke and therefore were considered as two trials, an early electrical stimulation trial (Wang-E), and a late electrical stimulation trial (Wang-L). Another one of the six (Kobayashi et al 1999) was also separated into two trials according to whether the deltoid muscle was stimulated (Kobayashi-D) or the supraspinatus muscle (Kobayashi-S). Therefore, in total, data from seven individual trials were extracted. Additional information was obtained from Linn (unpublished data) and Faghri (assessor blinding). Four trials with 145 participants were categorised as early electrical stimulation trials (Baker and Parker 1986, Faghri et al 1994, Linn et al 1999, Wang-E) and three trials with 38 participants were categorised as late electrical stimulation trials (Kobayashi-D, Kobayashi-S, Wang-L).

Similarity of inclusion criteria, sample characteristics, intervention and outcome measures between trials The inclusion criteria were slightly dissimilar across the early trials (Table 2). Two of the trials (Baker and Wang-E) selected subjects who already had shoulder subluxation before being admitted into the trial, whereas the other two

(Linn and Faghri) selected subjects who had very little muscle activity around the shoulder (and who therefore may or may not have already had subluxation). All of the late electrical stimulation trials selected subjects who had subluxation (Table 2).

The sample characteristics were similar across all trials (Table 2). Across the early electrical stimulation trials, the age ranged from 55 to 73 years old. Time after stroke before being admitted to the trial ranged from 2 to 49 days with about half of the participants (57%, 82), having an average admission time of less than 17 days after stroke. In the other 43%, the average admission time after stroke was 46 days in the control group and 49 days in the experimental group (Baker). Gender distribution was almost equal (49% male, 51% female). However, the majority of participants (61%) had left side hemiplegia. This may have been because subjects in one trial had to have reasonable communication and this would bias selection towards left hemiplegia (Linn). Across the late electrical stimulation trials, the average age ranged from 53 to 69 years old, and time after stroke before being admitted into trials ranged from 60 to 434 days. Seventy-six per cent of participants were male. Distribution between right and left side hemiplegia was not very different (47% had right hemiplegia).

All trials used electrical stimulation as an adjunct to conventional therapy (ie electrical stimulation plus conventional therapy was compared with conventional therapy). The application of electrical stimulation was similar across trials (Table 2). Across the early electrical stimulation trials, intervention was carried out over 4-6 weeks, 5-7 days/week. The duration of electrical stimulation was increased over time from between 1.5 and 2 hr/day to between 4 and 6 hr/day. Across the late electrical stimulation trials, intervention was carried out over six weeks, 5 days/week. The duration of electrical stimulation was increased over time from between 0.2 and 1.5 hr/day to between 0.5 and 6 hr/day. All trials applied electrical stimulation to supraspinatus and/or deltoid muscles. Most of the trials used stimulation frequencies greater than 30 Hz and all trials reported that the stimulation produced muscle contraction. All trials reported progressing the application of electrical stimulation by systematically increasing both the duration and duty cycle (ON:OFF) when subjects were able to complete a session without fatigue of the stimulated muscle(s). However, conventional therapy was not consistent across trials (Table 2) and there was not enough detail to judge whether differences would affect the outcome.

The method of measurement was similar across trials for subluxation but more varied for function and pain (Table 2). Subluxation was measured in millimetres from plain antero-posterior x-rays of the shoulder in all seven trials. Four trials measured subluxation by comparing the affected side with the unaffected side while three trials measured the affected side. Function was variously represented by measures of strength (Kobayashi-D,

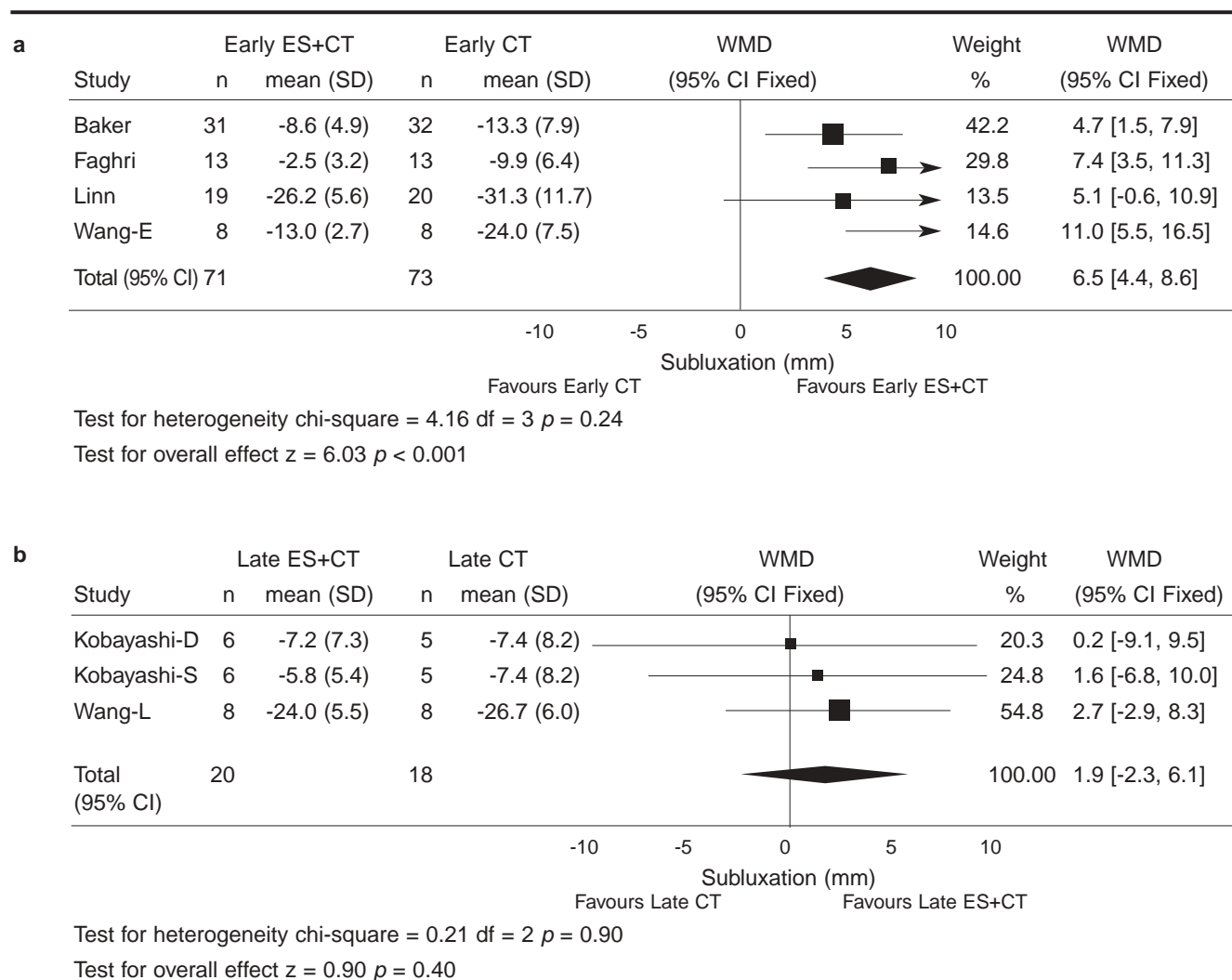


Figure 1. Examination of the efficacy of a) early electrical stimulation in the prevention of subluxation by pooling post-intervention data from 4 trials, and b) late electrical stimulation in the reduction of subluxation by pooling post-intervention data from 3 trials that measured subluxation in millimetres from plain AP x-rays of the shoulder. ES, electrical stimulation. CT, conventional therapy. WMD, weighted mean difference.

Kobayashi-S), tone (Faghri, Linn), EMG activity (Faghri, Kobayashi-D, Kobayashi-S), performance on functional scales (Faghri, Linn, Wang-E, Wang-L) or not at all (Baker). Pain was measured as self-report (Baker), request for drugs (Baker), pain-free passive shoulder external rotation (Faghri, Linn), pain-free active shoulder external rotation (Wang-E, Wang-L), verbal grading on passive shoulder external rotation (Linn), or visual analogue scale on active shoulder abduction (Kobayashi-D, Kobayashi-S).

Quality of trials Five trials were assessor-blinded, randomised controlled trials with baseline comparability between control and treatment groups. Two trials (Kobayashi-S, Kobayashi-D) were quasi-randomised and blinding was not reported. There was no report of the number of subjects who dropped out in any trial except for Linn. The mean PEDro score for the quality of the methods for the four early electrical stimulation trials was 5.8 (range

4-9) and for the three late electrical stimulation trials, 4.3 (range 4-5) out of a possible 10 points. (See Table 2 for PEDro score of individual trials.)

Pooled analysis The prevention of subluxation (Figure 1a) was examined by pooling post intervention data from the four early electrical stimulation trials that measured subluxation in millimetres from plain antero-posterior x-rays of the shoulder (Baker, Faghri, Linn, Wang-E). The weighted difference between means suggests that early electrical stimulation plus conventional therapy is superior ($p < 0.001$) to early conventional therapy and prevents 6.5mm of subluxation of the shoulder after stroke (95% CI 4.4 to 8.6). The reduction of subluxation (Figure 1b) was examined by pooling post-intervention data from the three late electrical stimulation trials that measured subluxation in millimetres from plain antero-posterior x-rays of the shoulder (Kobayashi-D, Kobayashi-S, Wang-L). The

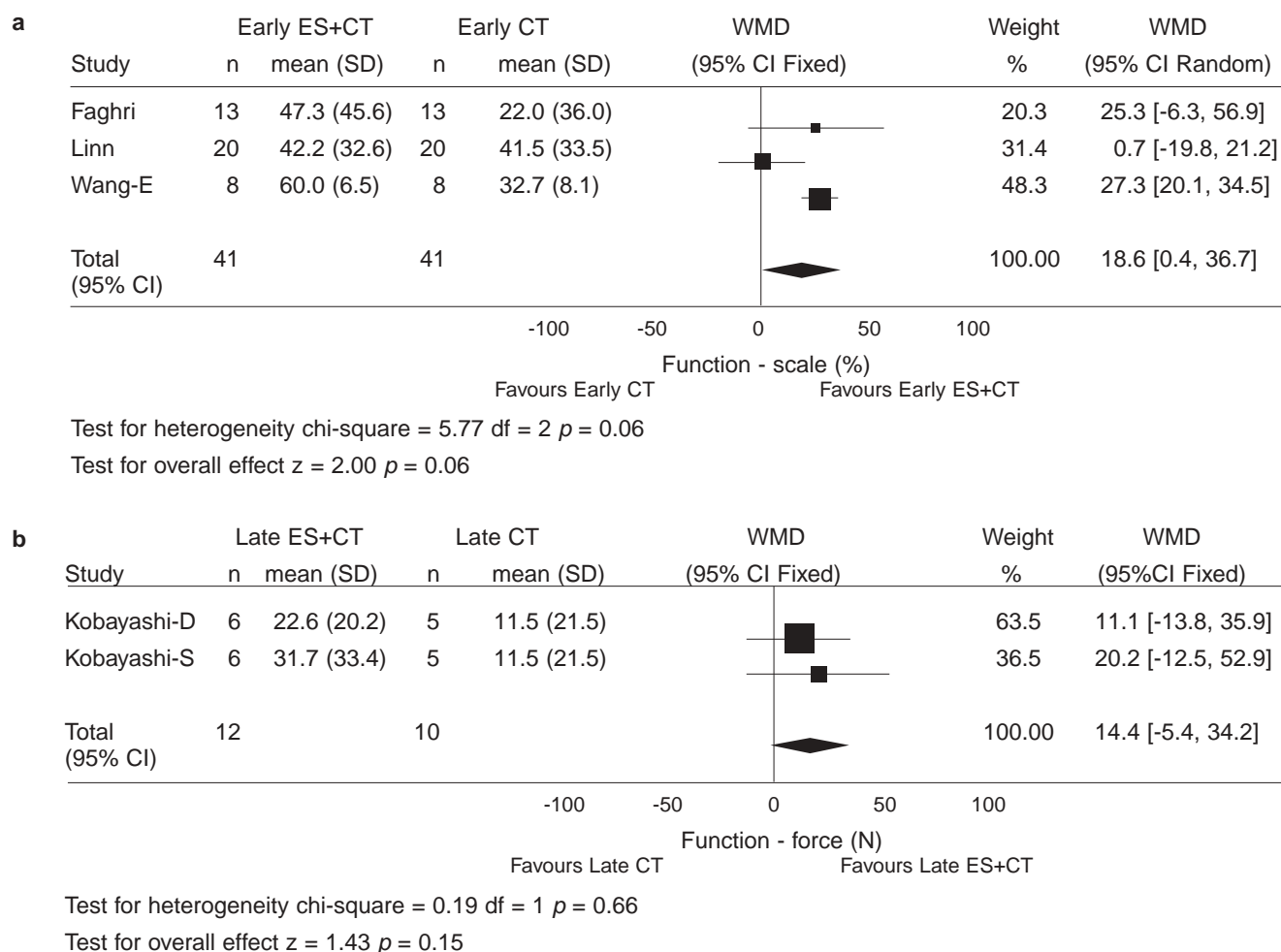


Figure 2. Examination of the efficacy of a) early electrical stimulation in improving early function of the shoulder by pooling normalised post-intervention data from 3 trials that measured upper limb function using scales and b) late electrical stimulation in improving late function of the shoulder by pooling change data from 2 trials that measured strength as maximum isometric abduction force in Newtons. ES, electrical stimulation. CT, conventional therapy. WMD, weighted mean difference.

weighted difference between means suggests that late electrical stimulation plus conventional therapy only reduces subluxation of the shoulder after stroke by 1.9mm and the 95% CI (-2.3 to 6.1) indicates that there is no evidence that it is superior ($p = 0.40$) to late conventional therapy.

The effect on early upper limb function (Figure 2a) was examined by pooling post-intervention data from the three early electrical stimulation trials that measured function using upper limb scales (Faghri, Linn and Wang-E). The scales were the Bobath assessment chart (Faghri), MAS scale (Linn) and Fugl-Meyer (Wang-E). In order to compare the trials, scores were converted to a percentage. Because the scales were similar in concept but differed in the categories measured, a random effects model was used. The weighted difference between means suggests that early electrical stimulation plus conventional therapy is superior

($p = 0.05$) to early conventional therapy in increasing function by 19% (95% CI 0 to 37). The effect on late upper limb function (Figure 2b) was examined by pooling change data from two late electrical stimulation trials that isometric abduction strength in Newtons (Kobayashi-D, Kobayashi-S). The weighted difference between means suggests that late electrical stimulation plus conventional therapy increases abduction strength after stroke by 14.4 N but the 95% CI (-5.4 to 34.2) indicates that there is no evidence that it is superior ($p = 0.15$) to late conventional therapy.

The prevention of pain (Figure 3a) was examined by pooling post intervention data from two early electrical stimulation trials that measured pain-free passive shoulder external rotation (Faghri, Linn) and one early electrical stimulation trial that measured pain-free active shoulder external rotation (Wang-E) using goniometry. The weighted difference between means suggests that early

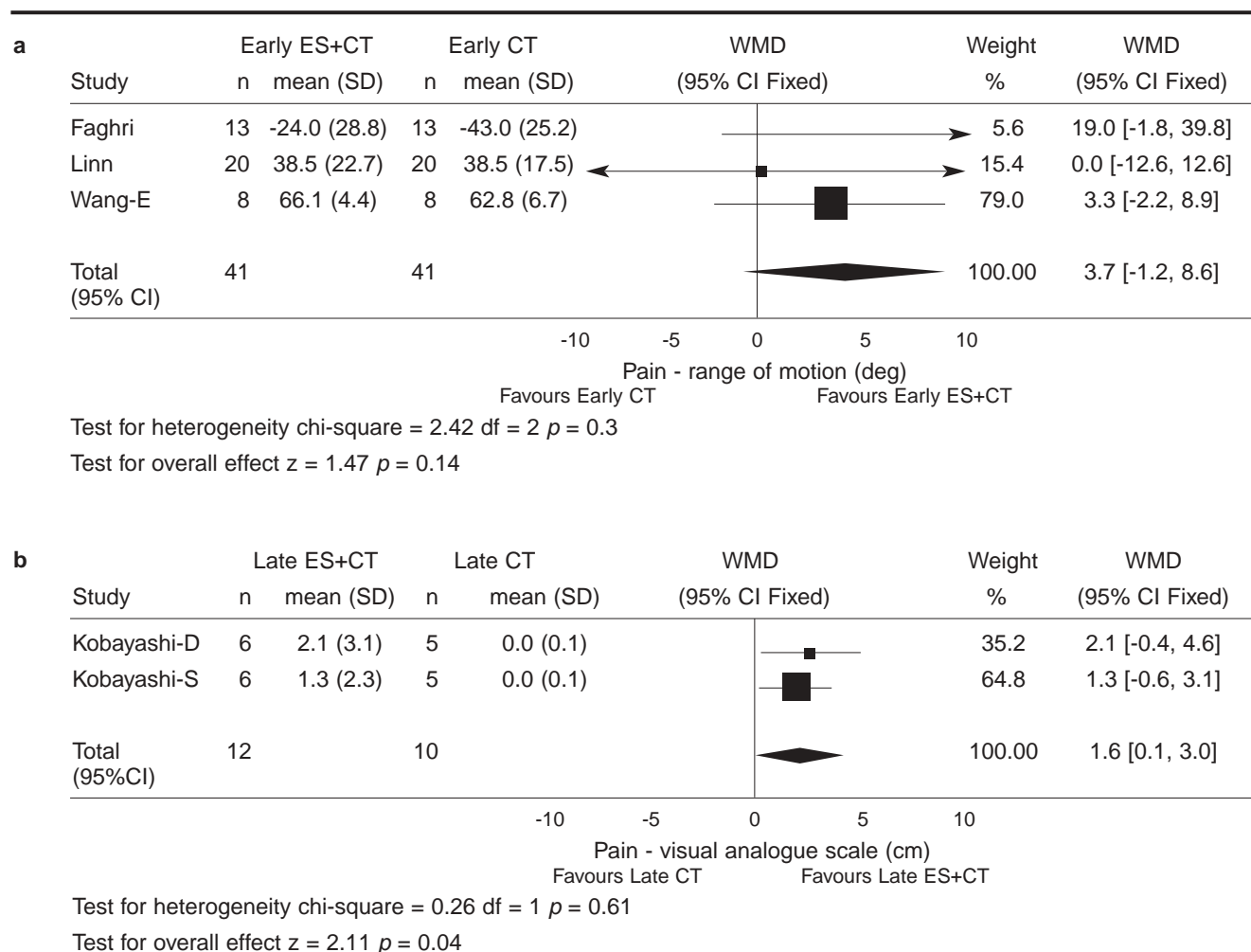


Figure 3. Examination of the efficacy of (a) early electrical stimulation in the prevention of pain by pooling post-intervention data from 2 trials that measured pain-free passive shoulder external rotation and 1 trial that measured pain-free active shoulder external rotation using goniometry and b) late electrical stimulation in the reduction of pain by pooling change data from 2 trials that measured pain on a 15 cm VAS during active shoulder abduction. ES, electrical stimulation. CT, conventional therapy. WMD, weighted mean difference.

electrical stimulation plus conventional therapy only maintains 4 degrees of pain-free passive/active shoulder external rotation after stroke and the 95% CI (-1.2 to 8.6) indicates that there is no evidence that it is superior ($p = 0.14$) to early conventional therapy. The reduction of pain (Figure 3b) was examined by pooling change data from two late electrical stimulation trials that measured pain by scoring a 15cm visual analogue scale during active shoulder abduction (Kobayashi-D, Kobayashi-S). The weighted difference between means suggests that late electrical stimulation plus conventional therapy is superior ($p = 0.04$) to late conventional therapy in maintaining an extra 1.6cm (10%) of pain-free active shoulder abduction after stroke (95% CI 0.1 to 3.0).

Discussion

This systematic review has demonstrated that there is evidence to support the efficacy of early electrical stimulation as an adjunct to conventional therapy for preventing shoulder subluxation and for increasing upper limb function, and of late electrical stimulation as an adjunct to conventional therapy in reducing pain.

Electromyographic studies show that supraspinatus and, to a lesser extent, posterior deltoid are key components in counteracting the inferior displacement of the glenohumeral joint (Basmajian and Bazant 1959, Chaco and Wolf 1971). Therefore, we included only trials that used stimulation frequencies greater than 30 Hz or

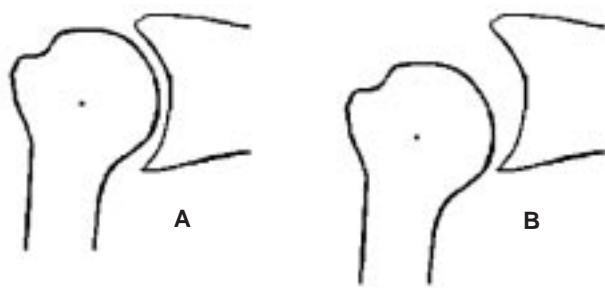


Figure 4. Scaled schematic of a) relation between humerus and glenoid fossa, and b) humerus subluxed the equivalent of 6.5mm relative to the glenoid fossa.

otherwise reported a motor response to electrical stimulation to ensure that muscle activity counteracted inferior displacement. Our findings indicate that there is a significant treatment effect of this type of electrical stimulation in preventing subluxation of about 6.5mm (Figure 4). Six-and-a-half millimetres of movement of the humeral head relative to the glenoid fossa is one sixth of the average height of the glenoid fossa (40mm) (McPherson et al 1997) and corresponds to a Grade 1 subluxation (van Langenberghe and Hogan 1988). In this review, we categorised trials into early and late electrical stimulation trials according to the average time after stroke to separate the effect of electrical stimulation for prevention versus reduction. We somewhat arbitrarily used two months to differentiate between early and late trials. In one of the early trials (Baker), even though the average admission time to the study was under two months, there was a wide range between subjects, which meant that some subjects were admitted later than two months. However, the test for heterogeneity of trials was not significant. Even if this trial is not included, there is prevention of a larger amount of subluxation (weighted mean difference 7.8mm, 95% CI 5.0 to 10.5) suggesting that the finding is robust.

Our finding that electrical stimulation prevents subluxation is in line with a previous review (Price and Pandyan 2001b) that pooled analysed change data from two trials (Faghri et al 1994 and Linn et al 1999). They reported a significant ($p < 0.001$) treatment effect of electrical stimulation of 1.1 SD (95% CI 1.66 to 0.60). However Linn's data is published in centimetres and this has not been converted to millimetres to be comparable with Faghri. Also, Faghri did not publish standard deviations or standard errors of the change scores and it appears that the authors have instead used the average standard deviation of the pre- and post-intervention scores. These procedures would have the effect of reducing the effect size. In addition, our pooled analysis includes four trials and this may explain why our finding is larger and less variable.

In contrast, the evidence does not support the treatment effect of late electrical stimulation or conventional therapy in reducing shoulder subluxation. This reflects the common

clinical perception that it is not possible to reduce shoulder subluxation once it has occurred.

Although the number of trials in this review is small, they are of reasonable quality (6/10), which suggests that the findings are believable and can be cautiously generalised. In addition, the application of electrical stimulation was similar across trials and can therefore be synthesised into a protocol. Since subluxation is more related to lack of muscle activity (Miglietta et al 1959, Najenson et al 1971, Smith et al 1982) than the presence of pain (Bohannon and Andrews 1990, van Langenberghe and Hogan 1988, Zorowitz et al 1996), the criteria to apply electrical stimulation should be loss of function as a result of paralysis of shoulder muscles after stroke. Therefore, we recommend that for those patients with a score on Item 6 of the Motor Assessment Scale for stroke (Carr et al 1985) of less than 4 early after stroke, electrical stimulation be applied daily to the posterior deltoid and supraspinatus muscles at more than 30 Hz, beginning at 1 hr/day, progressing to 6 hr/day, and continuing until the score on Item 6 of the Motor Assessment Scale reaches 4.

We were also interested in whether electrical stimulation applied so that it produced a motor response resulted in an increase in function and a decrease in pain. Our analysis indicates that early electrical stimulation as an adjunct to conventional therapy is superior to conventional therapy in increasing function. Even though the test for heterogeneity was not significant ($p = 0.05$), one trial (Wang-E) differed from the other two due to its unusually small standard deviations, so a sensitivity analysis was performed. When this trial is removed from the analysis, there is no significant effect of electrical stimulation plus conventional therapy on function (8% weighted mean difference, 95% CI -9 to 25), which is similar to the finding of the previous review (Price and Pandyan 2001a and 2001b). In addition, there is a 14 N increase in isometric abduction strength after late electrical stimulation. However, this finding was not significant, possibly because of small subject numbers. A previous meta-analysis on the effect of electrical stimulation on strength after stroke (Glanz et al 1996) has shown an increase in strength.

Finally, our analysis found no evidence that early electrical stimulation as an adjunct to conventional therapy is superior to conventional therapy in preventing pain. However, pain was measured indirectly as "pain-free range of shoulder external rotation". When it was measured more directly using a visual analogue scale, the application of late electrical stimulation was more effective than conventional therapy at reducing pain. These findings are in contrast with the previous review by Price and Pandyan (2001a and 2001b). However, Price and Pandyan included trials where the electrical stimulation produced a sensory response (Leandri et al 1990, Sonde et al 1998) as well as those that produced a motor response (Faghri et al 1994, Linn et al 1999).

In conclusion, this systematic review has demonstrated that early application of electrical stimulation applied in a way

that produces a motor response in deltoid and supraspinatus muscles is effective in preventing 6.5mm of shoulder subluxation. Therefore, electrical stimulation should be started as early as possible as part of best practice for those patients who are at risk of developing subluxation as a result of paralysis of shoulder muscles after stroke. This practice may also help to increase function and reduce another common secondary musculoskeletal side effect of stroke, shoulder pain.

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References

- Baker LL and Parker K (1986): Neuromuscular electrical stimulation of the muscles surrounding the shoulder. *Physical Therapy* 66: 1930-1937.
- Basmajian JV and Bazant FJ (1959): Factors preventing downward dislocation of the adducted shoulder joint. *Journal of Bone and Joint Surgery - American Volume* 41: 1182-1186.
- Binder-Macleod SA and Lee SCK (1997): Assessment of the efficacy of functional electrical stimulation in patients with hemiplegia. *Topics in Stroke Rehabilitation* 3: 88-98.
- Bohannon RW and Andrews AW (1990): Shoulder subluxation and pain in stroke patients. *American Journal of Occupational Therapy* 44: 507-509.
- Cailliet R (1980): *The Shoulder in Hemiplegia*. Philadelphia: FA Davis Company, pp. 89-106.
- Carr J, Shepherd R, Nordholm L and Lynne D (1985): A motor assessment scale for stroke. *Physical Therapy* 65: 175-180.
- Centre for Evidence-Based Physiotherapy (2002): The Physiotherapy Evidence Database (PEDro). <http://ptwww.cchs.usyd.edu.au/pedro> (accessed 26 August 2002).
- Chaco J and Wolf E (1971): Subluxation of the glenohumeral joint in hemiplegia. *American Journal of Physical Medicine* 50: 139-143.
- Chae J and Yu D (2000): A critical review of neuromuscular electrical stimulation for treatment of motor dysfunction in hemiplegia. *Assistive Technology* 12: 33-49.
- Chae J, Yu D and Walker M (2001): Percutaneous intramuscular neuromuscular electrical stimulation for the treatment of shoulder subluxation and pain in chronic hemiplegia: a case report. *American Journal of Physical Medicine and Rehabilitation* 80: 296-301.
- Chantraine A, Baribeault A, Uebelhart D and Gremion G (1999): Shoulder pain and dysfunction in hemiplegia: effects of functional electrical stimulation. *Archives of Physical Medicine and Rehabilitation* 80: 328-331.
- Chino N (1981): Electrophysiological investigation on shoulder subluxation in hemiplegics. *Scandinavian Journal of Rehabilitation Medicine* 13: 17-21.
- Dursun E, Dursun N, Ural CE and Cakci A (2000): Glenohumeral joint subluxation and reflex sympathetic dystrophy in hemiplegic patients. *Archives of Physical Medicine and Rehabilitation* 81: 944-946.
- Faghri PD, Rodgers MM, Glaser RM, Bors JG, Ho C and Akuthota P (1994): The effects of functional electrical stimulation on shoulder subluxation, arm function recovery, and shoulder pain in hemiplegic stroke patients. *Archives of Physical Medicine and Rehabilitation* 75: 73-79.
- Glanz M, Klawansky S, Statson W and Berkey C (1996): Functional electrostimulation in poststroke rehabilitation: a meta-analysis of the randomized controlled trials. *Archives of Physical Medicine and Rehabilitation* 77: 549-553.
- Hanger HC, Whitewood P, Brown G, Ball MC, Harper J, Cox R and Sainsbury R (2000): A randomized controlled trial of strapping to prevent post-stroke shoulder pain. *Clinical Rehabilitation* 14: 370-380.
- Hurd MM, Farrell KH and Waylonis GW (1974): Shoulder sling for hemiplegia: friend or foe? *Archives of Physical Medicine and Rehabilitation* 55: 519-522.
- Kimberley TJ and Carey JR (2002): Neuromuscular electrical stimulation in stroke rehabilitation. *Minnesota Medicine* 85: 34-37.
- Kobayashi H, Onishi H, Ihashi K, Yagi R and Handa Y (1999): Reduction in subluxation and improved muscle function of the hemiplegic shoulder joint after therapeutic electrical stimulation. *Journal of Electromyography and Kinesiology* 9: 327-336.
- Leandri M, Parodi CI, Corrieri N and Rigardo S (1990): Comparison of TENS treatments in hemiplegic shoulder pain. *Scandinavian Journal of Rehabilitation Medicine* 22: 69-71.
- Linn SL, Granat MH and Lees KR (1999): Prevention of shoulder subluxation after stroke with electrical stimulation. *Stroke* 30: 963-968.
- Mackenzie-Knapp M (1999): Electrical stimulation in early stroke rehabilitation of the upper limb with inattention. *Australian Journal of Physiotherapy* 45: 223-227.
- McPherson EJ, Friedman RJ, An YH, Chokesi R and Dooley RL (1997): Anthropometric study of normal glenohumeral relationships. *Journal of Shoulder Elbow Surgery* March/April: 105-112.
- Miglietta O, Lewitan A and Rogoff JB (1959): Subluxation of the shoulder in hemiplegic patients. *New York State Journal of Medicine* February: 457-460.
- Morley A, Clarke A, English S and Helliwell S (2002): Management of the subluxed low tone shoulder: review of the evidence. *Physiotherapy* 88: 208-216.
- Moseley AM, Herbert RD, Sherrington C and Maher CG (2002): Evidence for physiotherapy practice: a survey of the Physiotherapy Evidence Database (PEDro). *Australian Journal of Physiotherapy* 48: 43-50.
- Najenson T, Yacubovich E and Pikielni SS (1971): Rotator cuff injury in shoulder joints of hemiplegic patients. *Scandinavian Journal of Rehabilitation Medicine* 3: 131-137.

- Price CIM and Pandyan AD (2001a): Electrical stimulation for preventing and treating post-stroke shoulder pain. The Cochrane Library, Issue 1. Oxford: Update Software.
- Price CIM and Pandyan AD (2001b): Electrical stimulation for preventing and treating post-stroke shoulder pain: a systematic Cochrane review. *Clinical Rehabilitation* 15: 5-19.
- Shai G, Ring H, Costeff H and Solzi P (1984): Glenohumeral malalignment in the hemiplegic shoulder. An early radiologic sign. *Scandinavian Journal of Rehabilitation Medicine* 16: 133-136.
- Smith RG, Cruikshank JG, Dunbar S and Akhtar AJ (1982): Malalignment of the shoulder after stroke. *British Medical Journal of Clinical Research* 284: 1224-1226.
- Sonde L, Gip C, Fernaeus SE, Nilsson CG and Viitanen M (1998): Stimulation with low frequency (1.7 Hz) transcutaneous electric nerve stimulation (Low-TENS) increases motor function of the post-stroke paretic arm. *Scandinavian Journal of Rehabilitation Medicine* 30: 95-99.
- van Langenberghe HV and Hogan BM (1988): Degree of pain and grade of subluxation in the painful hemiplegic shoulder. *Scandinavian Journal of Rehabilitation Medicine* 20: 161-166.
- Verhagen AP, de Vet HC, de Bie RA, Kessels AG, Boers M, Bouter LM and Knipschild PG (1998): The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *Journal of Clinical Epidemiology* 51: 1235-1241.
- Wang R, Chan R and Tsai M (2000): Functional electrical stimulation on chronic and acute hemiplegic shoulder subluxation. *American Journal of Physical Medicine and Rehabilitation* 79: 385-394.
- Wang R, Yang YR, Tsai MW, Wang WJ and Chan RC (2002): Effects of functional electric stimulation on upper limb motor function and shoulder range of motion in hemiplegia patients. *American Journal of Physical Medicine and Rehabilitation* 81: 283-290.
- Yu DT, Chae J, Walker ME and Fang ZP (2001): Percutaneous intramuscular neuromuscular electric stimulation for the treatment of shoulder subluxation and pain in patients with chronic hemiplegia: A pilot study. *Archives of Physical Medicine and Rehabilitation* 82: 20-25.
- Zorowitz RD, Hughes MB, Idank D, Ikai T and Johnston MV (1996): Shoulder pain and subluxation after stroke: correlation or coincidence? *American Journal of Occupational Therapy* 50: 194-201.